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# MEASURING RESPIRATORY RATES AND VOLUMES OF EXPERIMENTAL SWINE

by

J. R. Songer, D. T. Braymen, R. G. Mathis, and J. L. Riley[1]

## Summary

For swine respiratory disease investigations, a device was constructed and evaluated for measuring the respiratory rate and volume of swine. When tested with a respiratory pump that delivered 7, 14, 21, 28, and 35 liters per min (l/min), it averaged 7, 14.2, 21.2, 28.4, and 35.3 l/min respectively for 10 measurements at each volume.

Swine weighing 102, 85, and 175 pounds had respiratory rates of 25, 26, and 15 respirations per minute and minute volumes of 13, 14.5, and 12.3 l/min respectively.

Estimation of animal respiratory exposure doses of infectious aerosols depends on: (1) the number of viable organisms per unit volume of air, (2) duration of exposure, (3) the respiratory tidal volume of the animal, and (4) the animal's respiratory rate. The first two factors can be readily obtained by sampling and quantitating the aerosol and by timing the exposure. Determining the third and fourth factors are the objectives of this continuing study.

Devices for measuring respiratory volumes in large animals were described by Kibler,[2] Kibler and Brody,[3] and McDowell and others.[4] Each of these devices consisted of a mask with inlet and outlet valves, a Douglas bag, and an air measuring device. Kibler used a flowrater, Kibler and Brody and McDowell and others used dry gas meters for air volume measurements. The respiratory volume measuring device (RVMD) described in this report followed similar design concepts.

## Equipment Design and Construction

*Swine restraining device.* A modified hog cholera hyperimmunization crate was used to restrain swine (figs. 1, 2 - 1).

*Swine mask.* The mask was constructed from a thin-wall copper pipe 4 inches in diameter and 8 inches long (fig. 3). One end was capped with ⅛-inch copper sheeting and the other beveled at a 45° angle. Two pieces of ¾-inch diameter by 2-inch long thin-wall copper pipe were silver soldered into the side of the large copper tube at right angles to each other. An inlet valve was fitted to one piece of pipe and an outlet valve to the other. A piece of refrigerator door gasket[5] was attached to the beveled end of the mask to effect a seal around the swine's muzzle. A device for attachment to the restraining device was affixed to the bottom of the mask.

*Respiratory rate counter.* A thermistor located in the inlet valve of the mask (figs. 1, 2, 5 - 15) was connected to a bridge circuit and power

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[2] Kibler, H. H. TIME-SAVING APPARATUS FOR RESPIRATORY EXCHANGE MEASUREMENTS. Science 107: 46. 1948.

[3] Kibler, H. H. and Brodey S. INFLUENCES OF TEMPERATURE 5° TO 95° F ON EVAPORATIVE COOLING FROM THE RESPIRATORY AND EXTERIOR BODY SURFACES OF THE JERSEY AND HOLSTEIN COWS. Mo. Exp. Sta. Res. Bul. 461, pp. 3-19. 1950.

[4] McDowell, R. E., Lee, D. H. K., Fohrman, M. H., and Anderson, R. S. RESPIRATORY ACTIVITY AS AN INDEX OF HEAT TOLERANCE IN JERSEY AND SINDHI X JERSEY ($F_1$) CROSSBRED COWS. J. Anim. Sci. 12: 573-581. 1953.

[5] Gasket No. 4868, Jarrow Products, Chicago, Ill.

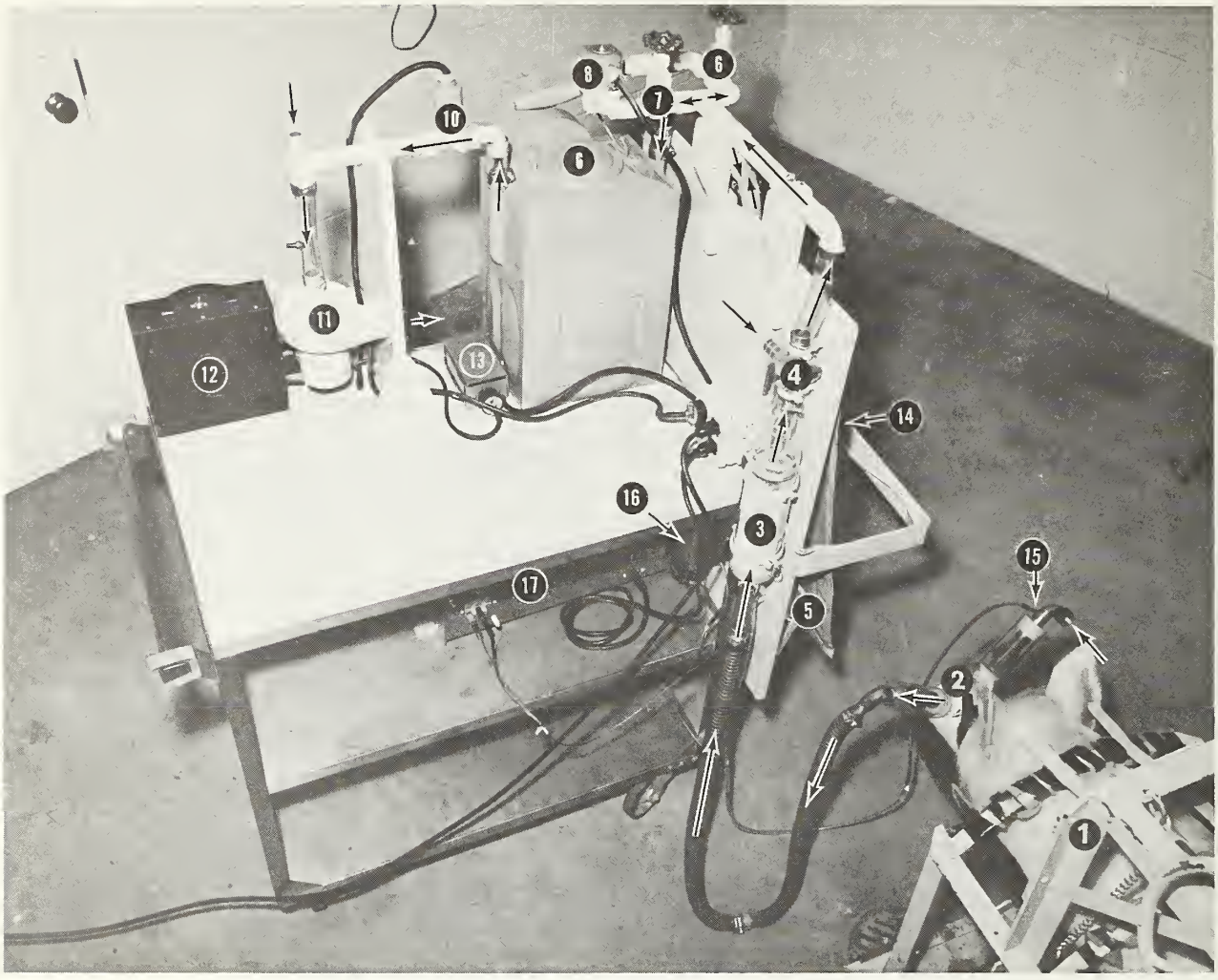


Figure 1. — The respiratory volume measuring device (RVMD): (1) restraining crate, (2) swine mask, (3) air drier, (4) hand valve 1, (5) Douglas bag, (6) hand valve 3, (7) hand valve 2, (8) solenoid valve 2, (9) dry test meter, (10) solenoid valve 1, (11) blower, (12) timer, (3) relay, (14) microswitches ($MS_1$ and $MS_2$), (15) thermistor, (16) power supply, (17) recorder.

supply (fig. 4). A recorder was also connected to the bridge circuit. With each inspiration of the animal, a sharp deflection was indicated on the recorder.

*Respiratory volume measuring device.* Figures 1, 2, and 5 illustrate the structure of the RVMD. Its major components are (a) an air drier, (b) a 100-liter Douglas bag, (c) a dry test meter, (d) a timer, and (e) an air blower. The principle of its operation is as follows: air exhausted by the animal passed through the air drier, the piping manifold, the dry test meter, and out of the system through the exhaust blower. The Douglas bag minimized the resistance of the system to the animal. The blower minimized the resistance of the dry test meter to the flow of air through the system.

## Operational Procedure for the RVMD

The two-way hand valve ($HV_1$, fig. 1 - 4) was opened to atmosphere. A swine was placed in the restraining device and fitted with the mask. The dry test meter (fig. 2 - 9) was set on zero and the timer (fig. 2 - 12) was set for a timing period of 5 min.

The two-way hand valve ($HV_1$) was closed to atmosphere. When the Douglas bag (fig. 2 - 5)

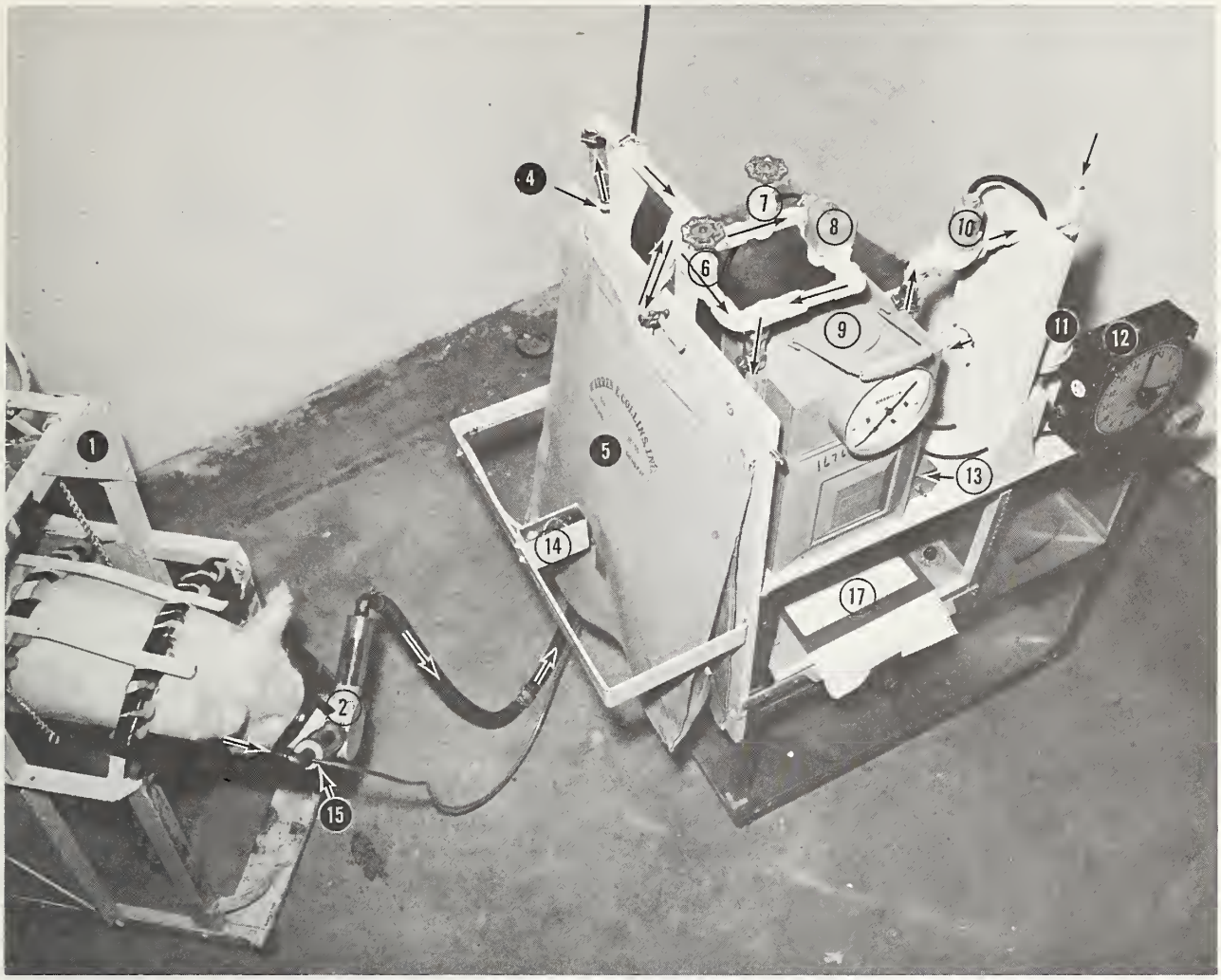


Figure 2. — The respiratory volume measuring device (RVMD): (1) restraining crate, (2) swine mask, (4) hand valve 1, (5) Douglas bag, (6) hand valve 3, (7) hand valve 2, (8) solenoid valve 2, (9) dry test meter, (10) solenoid valve 1, (11) blower, (12) timer, (13) relay, (14) microswitches ($MS_1$ and $MS_2$), (15) thermistor, (17) recorder.

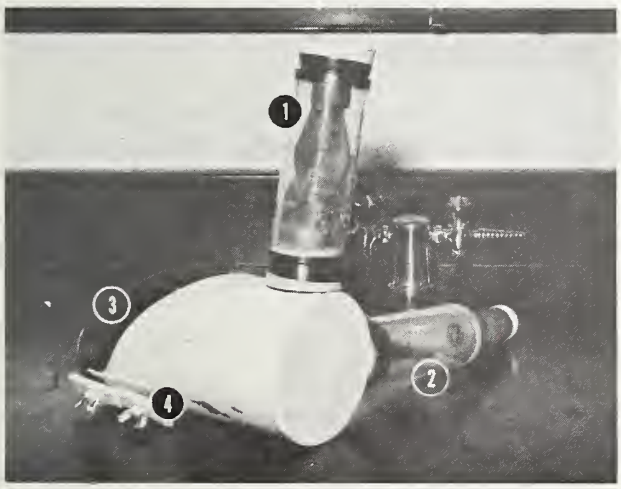


Figure 3. — Swine respiratory mask. (1) inlet valve, (2) outlet valve, (3) gasket, (4) anchoring device.

was approximately one-third full, it triggered microswitch 1 ($MS_1$) which opened solenoid valve 2 ($S_2$) as illustrated in figure 5. The Douglas bag continued to fill until microswitch 2 ($MS_2$) was triggered energizing the relay coil which locked-in, supplying continuous current to the timer. The timer supplied power to solenoid 1 ($S_1$). As long as the timer was on, $S_1$ was open.

Air, flowing through the system, was measured by the dry gas meter. Since the relay was locked-in, $MS_2$ no longer controlled. When the measurement interval was complete, the timer closed $S_1$, stopping the air flow. The respiratory volume for the 5-min period was read from the dry test meter. The respiratory rate was read directly from the recorder (fig. 2, 5 - 17).

The bypass and valve $S_2$ were used to maintain a relatively constant amount of air in the Douglas bag. If the bag overinflated, switch $MS_1$ opened $S_2$ valve allowing excess air flow through the bypass to the meter. When the bag returned to its desired position, $MS_1$ closed $S_2$ valve.

Hand valves 2 and 3 (figs. 1, 2, 5 - 6, 7) were preset to control the air flow volume through the system and the bypass.

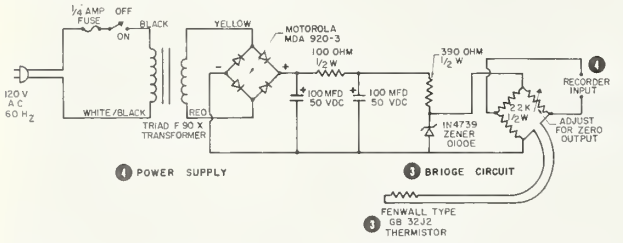


Figure 4. — Schematic of the respiratory rate indicator. (1) power supply, (2) bridge circuit, (3) thermistor, (4) recorder output.

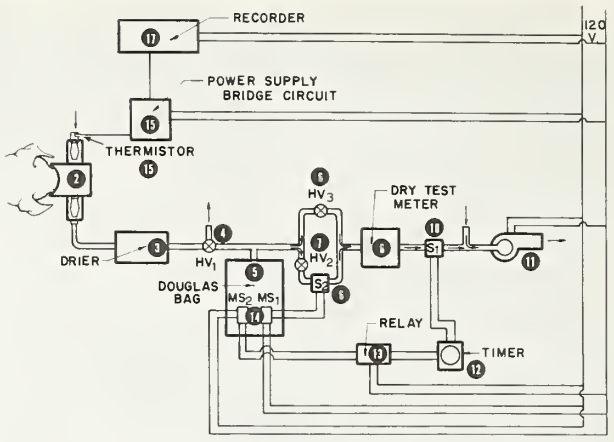


Figure 5. — Schematic of the respiratory volume measuring device. (2) swine mask, (3) air drier, (4) hand valve 1, (5) Douglas bag, (6) hand valve 3, (7) hand valve 2, (8) solenoid valve 2, (9) dry test meter, (10) solenoid valve 1, (11) blower, (12) timer, (13) relay, (14) microswitches ($MS_1$ and $MS_2$), (15) thermistor, (16) power supply, (17) recorder.

## Test Methods and Results

A Harvard (Model 607) respiratory pump[6] was used for evaluating the RVMD. The cylinder capacity of the pump was set at 700 $cm^3$ and measurements were made at 10, 20, 30, 40, and 50 strokes per minute. At these settings, the pump delivered 7, 14, 21, 28, and 35 liters per minute. Ten measurements were made at each of these flow rates. The results are shown in table 1. The average of the 10, 5-min averaged measurements were 7, 14.2, 21.2, 28.4, and 35.3 l/min. The mean difference between the RVMD volume and the respiratory pump volume was 0.23. Tolerance limits for this difference were -0.45 to 0.91.

*Table 1. — Results of the test of the RVMD with a respiratory pump*

| Number of measurements | Respiratory pump volume | RVMD volume[1] | Range of RVMD measurement |
|---|---|---|---|
| | *Liters per minute* | | |
| 10 | 7 | 7.0 | 6.8 - 7.4 |
| 10 | 14 | 14.2 | 14.0 - 14.4 |
| 10 | 21 | 21.2 | 20.2 - 21.6 |
| 10 | 28 | 28.4 | 28.0 - 28.8 |
| 10 | 35 | 35.3 | 35.2 - 35.4 |

[1] Respiratory volume in liters per minute is the average of 10, 5-min. averaged measurements.

The mean difference between the RVMD volume and the respiratory pump volume was 0.23. Tolerance limits for this difference were -0.45 to 0.91.

To determine the importance of the Douglas bag in the system, another test was made after removing the bag. The Harvard respiratory pump was set to deliver 700 $cm^3$/stroke at a rate of 30 respirations per minute for a flow of 105 liters in a 5-min period. The dry test meter registered a flow of 95 liters in 5 min for a loss of 2 l/min.

To measure resistance in the system, an inclined draft gage[7] was used. The respiratory pump was started, and the RVMD was operated normally with a flow rate of 35 l/min. Resistance was undetectable with the gage. After removing the Douglas bag from the system, resistance was again tested. This time the results showed that the pressure in the system rose to 0.3 inch of water and fell to 0 inch of water with each cycle of the pump.

## Measuring Swine Respiratory Volume

Three swine used in the study were acclimated to the restraining crate and mask before taking any measurements. If they became excited during a measurement period, that particular measure-

[6] Harvard Apparatus Co., Inc., Millis, Mass.

[7] F. W. Dwyer Mfg. Co., Michigan City, Ind.

ment was discarded. The animals usually did not fight the restraint unless they were held for an extended period of time. Each measurement was for a period of 5 min. Both respiratory rate and volume were measured.

Swine No. 1 weighed 102 pounds. Fourteen, 5-min measurements were made on this animal. Its average respiratory rate was 25 per minute with a range for the 5-min average of 23 to 31 respirations/min (rpm). Its average minute volume was 13 l/min with a range for the 5-min average of 10 to 18 l/min.

Swine No. 2 weighed 85 pounds. Twenty-four, 5-min measurements were made on this animal. Its average respiratory rate was 26 per minute with a range for the 5-min average of 21 to 35 rpm. Its average minute volume was 14.5 l/min with a range for the 5-min average of 8.2 to 19.6 l/min.

Swine No. 3 weighed 175 pounds. Fifteen, 5-min measurements were made on this animal. Its average respiratory rate was 15 per minute with a range for the 5-min average of 10 to 23 rpm. Its average minute volume was 12.3 l/min with a range for the 5-min average of 6.8 to 17.2 l/min.

*Comparing other measurement methods.* For the purpose of comparison, the respiratory volume of swine No. 3 was measured by two other methods. A 600-liter gasometer was used for a total measurement time of 75 min, in five, 15-min intervals. The average minute volume was 14.4 l/min with a range for the 15-min average of 11.5 to 15.7 l/min.

In the second method, expired air from swine No. 3 was collected in a 100-liter Douglas bag in 5-min intervals. The air from the bag was then metered through a wet test meter. From the 12 samples metered, the average minute volume was 10.6 l/min with a range for the 5-min average of 6.3 to 17.8 l/min.

## Discussion

When the RVMD was evaluated with the Harvard respiratory pump, its measurements were reasonably accurate and reproducible. Tests conducted with and without the Douglas bag established its importance in the system. Without it, respiratory volume measurements were inaccurate and the resistance in the system fluctuated between 0 and 0.3 inch of water.

Whereas the gasometer measurements averaged 2.1 l/min greater than those with the RVMD and measurements through the wet test meter averaged 1.7 l/min less, all measurements were within the range experienced with the RVMD.

From this study, results show that not only is there extreme variation in respiratory volume and rate between otherwise comparable swine but also extreme variation in the same swine at different times. Because of these variabilities, respiratory volumes should be determined at the time of respiratory exposure to aerosols.



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